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**PROSPECTS FOR INCREASED AFRICAN COAL PRODUCTION
AND UTILIZATION**

* Paper prepared by the Joint ECA/UNIDO Industry Division for the Natural Resources Division for presentation at the Regional Workshop on the Role of Coal in Accelerated African Economic Growth (11-15 July 1983). For technical reasons this document is not edited.

I. THE LAGOS PLAN OF ACTION AND PROGRAMME OF THE INDUSTRIAL DEVELOPMENT DECADE FOR AFRICA

A. Growth Objectives of the Lagos Plan of Action

The Lagos Plan of Action (LPA) and the Final Act of Lagos (FAL), whose fundamental objectives are to lessen the excessive external dependence of African economies and achieve self-sustained growth in the African region were adopted against the background of worsening economic situation and poor development prospects for African countries.

The Plan envisages among other things the attainment of sovereignty over natural resources by African member States through the increased use of indigenous natural resources.

B. Programme for the Industrial Development Decade for Africa

The programme intends to lay the foundation for the phased development of : Building materials, metallurgical, mechanical, chemical and energy industries which offer a great potential for increased production and utilization of African coal.

II. COAL RESOURCES IN AFRICAN COUNTRIES

A. Coal Resources and Production

African coal resources (anthracite, bituminous and lignite) are concentrated in the Eastern and Southern African subregion. The most important coal deposits are found in the continental formation called Karro system of the Southern African subregion. Karoo coals are generally bituminous high ash coals. Fast resources are found in Central Africa. There are also coal prospects in West Africa. In North Africa the coal reserves have not been fully evaluated.

(i) Algeria

Coal formations are found in the Colom - Bechar - Kenadza and Abadla basins. Reserves are estimated at one billion tonnes of medium volatile coking coal. The sulphur content is mainly organic and therefore cannot be reduced by washing. Production from Bechar - Kenadza coal fields reached a figure of 300,000 in 1960 but dropped to 13,000 tons in 1970 because of resources depletion. By 1975 mining stopped because resources were finally depleted. Development work in a new area is being carried out with a view to extracting 500,000 tons of coal per year for local consumption. Meanwhile Algeria imports up to 1.2 million tonnes of coking coal annually from USSR, West Germany and Poland.

Demand for coking coal is likely to rise from the current 1.2 million to 1.8 million tonnes in 1985. The Algerian industry is expected to raise steel production from the current one million to two million tonnes by 1985.

(ii) Angola

Coal resources of Angola are not documented. However the tectonics of the sedimentary formations indicate numerous and important indications and accumulations of hydrocarbons. An asphalt deposit is reported at Libongo - Coxites with a 10-15 per cent asphalt content. Numerous oil and gas deposits have been discovered. Oil and gas are produced in Cabinda.

(iii) Botswana

Coal has been known to exist in Botswana since the beginning of the last century. Exploration for coal was conducted between 1952 and 1962. Main coal reserves are in the Serowe - Morupule and Mmamabula areas of eastern Botswana. Botswana coal has a high ash content with medium calorific value. The best coal so far found occurs within the Morupule area where approximately 6.5 billion tonnes of In-situ coal have been identified. In the Mmamabula area 470 million tonnes of coal have been identified. Very large resource of high ash bituminous coal have been found in the Dutlwe and Letlhakeng areas. Beneficiation tests have indicated that coal suitable for the export markets can be produced. However coal with satisfactory coking properties has not yet been found.

Table 1 below summarises the coal resources of Botswana.

The Colliery at Morupule, while capable of a considerably larger production is at present producing about 300,000 tonnes of coal per year for the local market which consists of the power station and smelter at Selebi-Phikwe and power station at Gaborone.

Table 1 : Coal Resources of Botswana

Coal Field	Area (Square kilometers)	Total In-Situ Resources (mil.tons)	Moisture (%)	Ash (%)	Volatiles (%)	Fixed carbon (%)	Calorific Value (MJ/kg)
Morupule	520	6,500	4.63	23.27	27.50	44.60	22.92
Manabula	260	3,000	5.90	16.80	25.05	52.65	24.11
Mojibana	250	1,300		30.00			21.00
Letlhakeng	660	2,400					23.60
Dutlwe	350	2,000		12.50			25.00
Total	2,040	15,200					

Source : The Coal Resources of Botswana, Geological Survey
Republic of Botswana

(iv) Egypt

Detailed coal exploration conducted between 1958 and 1962 resulted in the discovery of coal deposits of Ayun Musa, Wadi Thera, and Maghara in Sinai Peninsula. The Ayun Musa deposit is estimated at 37 million tons of coal. Unfortunately the coal is found at great depth with high pressure underground water in a complicated geological structure. The deposit is considered uneconomic.

The Thera coal deposit is estimated at 15 million tonnes of proven reserves and 60 million tonnes of probable reserves. The deposit has not been evaluated. The Maghara coal deposit is estimated at 52 million tons of total resources (of which 36 million are Workable). The Maghara coal has coking properties and is considered suitable as a blend with imported coking coals. Characteristics of Egyptian coal are summarized in table 2.

Exploitation of the Maghara coal is planned to resume in April 1986 with an ultimate installed capacity of 500,000 tonnes per year run-of-mine coal. Egypt is currently importing 1.5 million tonnes of coking coal from Australia, USA and USSR. Demand for coking coal is estimated at 2.1 million by 1987. In view of expansion plans for the Egyptian iron and steel industry it is envisaged that more coking coal will be consumed by the year 2000 when Egypt is expected to produce about 11 million tonnes of Blast Furnace/Basic oxygen/BOF route crude steel.

Table 2 : Characteristics of Egyptian coal

Coal Deposit	Reserves (million tonnes)		Moisture (%)	Ash (%)	Volatile Matter (%)	Fixed carbon (%)	Calorific Value Kcal/kg
	Proven	Probable					
Ayun Musa		37	12.40	16.15	41.10	30.15	5,820
Thorn	15	60	2.00	39.00	22.00	37.00	4,053
Maghara	28	3	4.90	6.80	43.40	39.90	7,500

Source : Prospects for African co-operation in the coking coal for iron and steel and related industries; ECA 1983

(v) Ethiopia

Lignite reserves are reported in Gondar, Shoa and Wolo regions. These reserves have not been fully assessed. Natural gas and petroleum occurrences have been reported in the Red Sea and Ogaden regions.

(vi) Madagascar

Bituminous sandstones have been identified in the Diego Basin over an area of 5,000 square kilometers on shore and 20,000 square kilometers offshore. Similar deposits have been identified in the Majunga Basin over 44,000 square kilometers onshore and 23,000 square kilometers offshore.

Madagascar is one of the few countries in the world which possess oil sand (the others being Albania, Canada, Rumania, USA, USSR and Trinidad).

The oil sands are located at Bemolanga in the north-western region covering about 390 square kilometers. Contained hydrocarbons are estimated at 1.75 billion barrels ^{1/}.

^{1/} McGraw-Hill Encyclopedia of Energy; Page 534 (1976)

(vii) Hali, Béni, Niger, Sierra Leone and Upper Volta

Lignite deposits have been reported. These deposits have not been evaluated. Detailed exploration and subsequent exploitation will primarily be influenced by the local and subregional demand.

(viii) Malawi

The coal formation cover 90 square kilometers of area between Livingstonia and Chivato. The coal field is broken up by several major fault zones. Exploitation possibilities are complicated by ground water conditions and variations in quality and seam thickness. Characteristics of Malawi coal are summarized in table 3. Workable coal seams exist within the Htandira Basin and parts of the North Rukuni Basin. Reserves have not been estimated.

Table 3 : Characteristics of Malawi Coals

Coal Deposit	Moisture (%)	Volatiles (%)	Fixed carbon (%)	Ash (%)	Calorific Value (Bru/lb)
Kaziviziwi	5.50	30.92	51.13	12.34	11,432
Chombe	1.80	21.85	52.35	24.00	10,339
Chizindiri	12.06	32.17	14.11	41.55	
Rumphi	2.65	29.72	49.45	15.91	11,370
Mean	4.22	23.73	40.33	32.36	8,540

Source : The Geology of the Usukuma Area
geological survey Department; Ministry of Agriculture and Natural Resources, Malawi Government Printers; 1975 page 51.

(ix) Morocco

Coal resources are estimated at 120 million tonnes of in-situ reserves (of which 40 million tonnes are exploitable). The coal is located at Jerrada in the Oujda region. Exploitation is handled by a national company, les Charbonages Nord-Africains. Production includes anthracite, balls and briquettes. In 1976 anthracite production was 702,000 tonnes and that of balls and briquettes was 15,600 tonnes.

(x) Mozambique

The main coal basins are located in Fata and Niassa provinces. The most important being Montize, Macanha, Quicando-Vuzi and Samanga basins. The Montize basin has been designated as the coal producing centre up to 1990. Development of the Macanha-Uzi will be undertaken after 1990. Quicando and Samanga deposits have not yet been fully investigated.

Reserves of the Chipanga seam (the only one quantified so far) is estimated at 70 million tonnes proven and 150 million tonnes probable reserves. The whole of Montize basin is thought to have 2 billion tonnes of coal. The reserves of Macanha-Vuzi are placed at 3 billion tonnes. Characteristics of Mozambican coals are summarized in table below 4.

The Montize coal mine is a state enterprise with the technical collaboration of the German Democratic Republic. Operations consist of an underground mine. Production in 1981 was 100,000 tonnes (out of which 21,000 tonnes were exported).

Table 4 : Characteristics of Mozambican coal

Coal Deposit	Moisture (%)	Volatiles (%)	Fixed carbon (%)	Ash (%)	Calorific Value Btu/lb
Chipanga	1.38	18.00	58.30	22.30	11,890
Macanha-Vuzi			34.65	12.01	

Source : Prospects for African co-operation in the coking coal for iron and steel and related industries; ECA 1963

(xi) Nigeria

The principal coal deposits lies along a 160 kilometer coal belt which runs in a northern direction from Inyi through Enugu, Nsukka, Ezime and Otukpa to Okaba, Ogbayaga and Dekker. Major coal fields are : Inyi-Enugu, Ezime-Otukpa and Okaba-Ogbayaga. These coal fields have reserves estimated at 500-600 million tonnes. Lignite deposits are distributed along a 100 kilometer belt extending from Aba through Umuahia and Orlu to Agushi - Asaba then Obonkpa. The lignite reserves of the Agushi - Asaba - Obonkpa are estimated at 50 million tonnes. Characteristics of coal from major coal fields are summarize in table below 5.

The Nigerian coal corporation operate the Okpara and Ogyesasa underground mines together with Okaba and Orukpa open cast mines. Total coal production in 1982 was 740,000 tonnes. Expansion projects are underway. It is expected that by 1986 total coal production will be 3.8 million tonnes. Demand for coal is expected to rise to 3.8 million in the energy sector by 1986 due to the construction of a number of coal-fired thermal power plants.

Major projects are underway at the Enugu underground mines involving driving of about 40 kilometers of underground access roads, replacement of exhausted longwall faces and subsequent installation of additional longwall faces to facilitate the production of 2.5 million tonnes of coal per year. A total of 10 longwalls are expected to be operational by 1985.

Table 5 : Characteristics of Nigerian coals

Coal Field	Moisture (%)	Ash (%)	Volatiles (%)	Fixed carbon (%)	Calorific Value Kcal/kg
Enugu	3.50	21.60	36.40	43.00	6,243
Orukpa	8.30	8.00	43.30	48.70	6,936
Okaba	9.6	10.00	39.40	50.60	6,588

Source : Prospects for African Co-operation in coking coal for iron and steel and Related industries; ECA 1983

Other expansion programmes are at Okaba open cast mines and development of new coal mines such as Orukpa and Orboyoga.

Major coal consumers in 1985 will be the Okaba coal carbonization plant (600,000 tonnes); Cement industry (500,000 tonnes) and Nigerian Steel Authority (300,000 tonnes). The Ijaukuta Steel Company is expected to import 1.2 million tonnes of coking coal in 1985.

(xii) Swaziland

Coal resources are estimated at 5,000 million tonnes In-situ (of which 1,820 million tonnes are exploitable). Important coal reserves are Iphaka, Mtendekwa and Maloma. Exploration work has been sponsored by the Government

in the Mpoke area. Anglo-American Corporation of South Africa Ltd (AAC) undertook this work. Shell Coal (Swaziland) Pty Ltd and Sir Alfred Hollpine and Sons Ltd have undertaken further exploration work. Characteristics of Swaziland coals are summarized in table below 6.

The Mpoke colliery produced 166,000 tonnes of coal in 1978. Expansion plans include a proposal to construct a 200 Megawatt thermal Power station at Mpoke colliery and the development of a new coal mine at Maloma with an annual capacity of 500,000 tonnes.

Table 6 : Characteristics of Swaziland coals

Coal Deposit	Moisture (%)	Ash (%)	Volatiles (%)	Sulphur (%)	Calorific Value MJ/kg
Mpoke	1.30	23.10	12.60	0.35	26.11
Maloma		11.00	5.70	0.60	30.64

Source : Annual Report of the Geological Survey; Ministry of Industry, Mines and Tourism, 1975 (pages 10-27)

(xiii) United Republic of Tanzania

The two best known coal deposits are Mchuchuma - Keteuka and Songwe-Kiwira coal fields. Both fields have been investigated. Coal resources are estimated at 360 million tonnes (of which 200 million tonnes are exploitables). Mchuchuma deposit covers an area of 15 square kilometers. Reserves are estimated at 187 million tonnes. The coal thickness is 20-25 meters. Of the three seams of the Mchuchuma coals the lower and middle seams have been evaluated for coking characteristics. Results showed that beneficiated coals could produce coke. Characteristics of Tanzania coals are summarized in table 7 below.

Table 7 : Characteristics of Tanzanian coals

Coal Deposit	Moisture (%)	Ash (%)	Fixed carbon (%)	Volatile matter (%)	Calorific Value (KJ/jg)
Mchuchuma	4.5	14.30	56.15	28.85	30,600

Source : Feasibility study : Iron and steel industry based on Liganga
iron ore and Mchuchuma coal BTZ; 1979

(xiv) Zambia

Coal occurs in the Karroo-system much in the same way as all coal deposits of Southern Africa. Known Zambian coal resources are in the Mid-Zambezi Valley. The Luangwa and Luano Valleys are also covered by the Karroo system. A total of 36 coal occurrences throughout Zambia are recorded. The mid-Zambezi valley has 24 coal occurrence of which the Siyankondobo, Mulungwa, Maza-Sinkumba and Mbandwe have been well investigated. The total coal reserves of the Mid-Zambezi Valley are estimated at 124 million tonnes. Characteristics of the Zambian coals are summarized in table below 9.

In 1972 coal production was 958,700 tonnes from Mbandwe Mine-whose capacity is 1.5 million tonnes per year.

Table 8 : Characteristics of Zambian coal

Coal Deposit	Moisture (%)	Ash (%)	Volatiles matter (%)	Fixed carbon (%)	Calorific value (Btu/lb)
Siyankondobo		17.40	17.40	65.40	
Mbandwe	1.90	24.50	21.85	53.30	10,230
Siyambalala	1.09	23.10	27.49	48.31	11,368
Bondo	3.53	18.38	34.22	43.87	10,760

Source : Mid-Zambezi Coal fields of Zambia, Geological survey Department,
Ministry of mines.

(xv) Zimbabwe

There are two main groups of coal formations. In the north are the Middle Zambezi Valley coal formations and in the south the Sabi-limpopo coal formations. The Wankie coal deposit is the most important of all the coal formation. The Wankie formation contains more than 3 billion tonnes of coal resources. The resources of Sabi-limpopo Valley in the South have not been estimated. The total coal resources of Zimbabwe are in excess of 7.13 billion tonnes of coal.

The present Wankie coal concession area covers 160 square kilometers. The coking coal seam is estimated at 478 million tonnes. Characteristics of Wankie coal are summarized in table 9 below.

Production at Wankie was 2.67 million tonnes in 1981. Room-and-pillar mining method is used. As a result a large quantity of coal is left underground at roof-support. According to European experience room-and-pillar has been found to be the most inefficient of all underground mining methods resulting in a loss of up to 65 per cent of the total coal resources in the deposit ^{1/}. In the Zimbabwe case, long wall method is not used because of the volatile nature of coal and the risk of spontaneous combustion when caving take place.

Coal from Wankies is converted into coke consumed by ZISCOSTEL and foundries in Bulawayo. High ash coal is fired at Wankie to produce electricity.

Table 9 : Characteristics of Wankie coal

Coal Deposit	Moisture (%)	Volatiles (%)	Ash (%)	Fixed carbon (%)	Calorific value (MJ/kg)
Wankie	1.00	24.00	10.00	65.00	31.40

Source : Prospects for African co-operation in coking coal for iron and steel and Related Industries, ECA 1983

^{1/} Economic Commission for Europe and Energy conservation : Recent Experiences and Prospects E/ECE/985; page 2, (1980)

(xvi) Development of coking coal resources and infrastructure in Africa

The coal resources of African countries are summarized in Table 10 below. Coking coal of commercial value is found in Botswana, Mozambique and Nigeria. The rest of African coals are suitable mainly for domestic use.

The vast coal resources of Botswana, Mozambique, Senegal and Zimbabwe offer of great potential for development. This is coal development as well as the development of associated infrastructure. Botswana has contemplated the construction of a new railway leading to the sea. This will require the consent and co-operation of neighbouring countries with a view to the Botswana is landlocked.

Intra-African trade in coal will be constrained by available coal handling facilities and inadequacy of transportation infrastructure for coal. Bearing in mind that Botswana, Mozambique, Senegal and Zimbabwe are potential exporters of coal whereas countries such as Egypt, Egypt and Nigeria are potential importers, the situation regarding infrastructure will be a major constraint to coal trade.

Mozambique possesses three coal ports: Beira, Nampula and Maputo. Present capacity of Beira is 30,000 tons per year. Beira is a natural deep harbour but has limited infrastructure. Zimbabwe is a landlocked country that requires access to the sea, this is also the case with Botswana. In Nigeria, the coal handling and transportation infrastructure in the form of railways, ports, harbours and terminals for coal are just in the process of development.

TABLE I

Table 10 : Summary of the Coal Resources of African Countries (Units in billion tons)

Country	Coal resources		Lignite resources		Total exploitable coal resources	
	Geological	Exploitable	Geological	Exploitable	Geological	Exploitable
	in situ	(reserves)	in situ	(reserves)	in situ	(reserves)
Algeria	1 030	20-100	n.a.	n.a.	1 030	20
Angola	100	-	30-500	10	100	30
Botswana	130 000	500-5000	-	-	130 000	500
Egypt	40	5	n.a.	2	40	7
Ethiopia	-	-	n.a.	10	-	10
Kenya	300	90-120	100	30	400	120
Libya	-	-	n.a.	3	-	3
Malawi	50	15	-	-	50	15
Morocco	120	50	n.a.	n.a.	120	50
Mozambique	400	30-100	-	-	400	50
Niger	-	-	15	20(?)	-	30
Nigeria	100	90	70	90(?)	170	140
Sierra Leone	-	-	n.a.	2	-	2
Senegal	-	-	n.a.	n.a.	-	-
Swaziland	5 000	1 000	-	-	5 000	1 000
United Republic of Cameroon	900	-	n.a.	n.a.	900	-
United Republic of Tanzania	300	700(?)	-	-	300	250
Zaire	1 180	73	-	-	1 180	75
Zambia	220	0	-	-	220	5
Zimbabwe	7 130	1 300	-	-	8 430	1 300
Developing Africa	115 000	35 000	20 000	150	135 000	35 150
South Africa	66 190	20 900	-	-	87 090	20 900
Total Africa	182 000	31 200	20 000	150	202 000	31 300
Total world	7 725 534	792 720	307 000	29 520	8 032 534	821 820
Africa's	2 330	6,300	0,330	0,005	2,660	6,305

* Sources : World Energy Conference 1977, World Bank Reports, International Geological Correlation Project 1970, IGC Secretariat.
The following have not been included; sub-economic lignite reserves in Tunisia, Egypt, United Republic of Cameroon, Benin, Nigeria, Upper Volta, etc.

+ According to local sources, the geological coal resources of the United Republic of Tanzania in 1980 may be four times higher and Zambia's exploitable coal resources seven times higher than shown here.

III. OPPORTUNITIES FOR INCREASED UTILIZATION OF COAL IN AFRICA COUNTRIES

A. Coal and other sources of energy

As an energy source, the future of coal and its role in the socio-economic development of African countries are inextricably associated with the pattern of energy uses. It is a well known fact that the evolution of energy sources from human muscles to mechanical energy brought about industrialization. Here in Africa, industrialization patterns will determine the preferred energy sources. Options of Sources of Energy for Africa's industrialization are:

- (i) Fossil fuels, Coal, Crude petroleum, refined petroleum products, natural gas, derived synthetic gases, shale oil and tar sands
- (ii) Hydro-electricity and thermal electricity
- (iii) Renewable energy resources : fuel wood, farm wastes, windpower, tidal, solar, geothermal energy, industrial and municipal waste
- (iv) Nuclear energy

Each form of energy has a set of technologies and economics associated with primary production, extraction, transportation or supply, conversion, distribution and end-use. End-uses are basically three : power, heat and light. Industrial energy conversion modes are : electricity, industrial (such motors, engines, generators and converters), direct process heat such as steam, direct heating and firing. Consuming sectors are grouped under : residential commercial, industrial and transportation.

On the basis of costs, foreign exchange constraint and technological convenience, not all forms of energy indicated above are ideal for the African situation. Tables 11 and 12 summarize the situation quite clearly. These energy sources are not interchangeable in terms of end-use. As an example gasoline and diesel oil are the most convenient energy sources for transportation; electricity natural gas and LPG for domestic heating in urban areas; charcoal and firewood in rural areas. Electricity is the most convenient source of energy for lighting, industrial prime movers moves and domestic appliances. The issue that we are confronted with in Africa concerns the extent to which coal can be used as a primary source of electricity, synthetic substitutes for gasoline and diesel oil as well as a source of direct heat in industry and homes and also as a raw material for conversion in industrial processes to yield intermediate and final products.

Table 11 : Comparative Costs of Domestically Produced Fuels from Different Sources a/

(1980 US dollars per barrel of crude oil equivalent)

	Range of Domestic Prices		Imported Equivalent
1. <u>Primary Energy</u>			
Crude Oil	6.00	to 15.00	30.75 ^{b/}
Natural Gas	2.25	" 11.00	27.00 ^{c/}
Gas (manufactured)	4.50	" 15.00 ^{d/}	14.00 ^{e/}
2. <u>Secondary Energy</u>			
(a) <u>Derived from Crude Oil</u>			
Gasoline - Primary Distillate	9.40	" 21.00	43.50
- Cracking of fuel oil	11.00	" 21.00	43.50
Kerosene	11.30	" 25.40	46.00
LPG	10.00	" 25.00	42.50
Fuel Oil	7.20	" 13.50	27.45
(b) <u>Derived from Coal</u>			
Gasoline	40.00	" 60.00	43.50
(c) <u>Synthetic Fuels</u>			
Ethanol from Molasses/			
Sugarcane	25.00	" 45.00	43.50 ^{f/}
Shale oil	25.00	" 35.00	30.75
3. <u>Renewable Energy</u>			
Firewood	3.00	" 20.00	46.00 ^{g/}
Charcoal	30.00	" 80.00	46.00 ^{g/}

a/ Based on delivered cost to major consumers

b/ Based on posted price for Saudi Arabian Light Crude, 1st June 1980

c/ Based on Imports of liquified natural gas or fuel oil

d/ Includes cost of infrastructure

e/ Cost of imported steam coal

f/ Cost of imported gasoline

g/ Cost of imported kerosene

Source : World Bank : Report No. 3076 Energy in the Developing Countries

Table 12 : Comparative costs of power generation based on various types of fuel (Case of oil Importing Developing Countries)
(Delivered cost to major consumers)

Generator Type	Investment cost ^{a/} US Dollars per KW Installed	Fuel Cost	Power Cost
		1980 US\$/KW	1980 US\$/KW
Hydropower - Large, High Head	1100	n.a.	2.4
- Low Head Mini-Hydro	3500	n.a.	12.7
Diesel - Large, Heavy Oil Fuel Coastal Location	1000	4.2	6.7
- Small, Light Oil Fuel Inland Location	800	10.9	13.2
Steam - Large, Gas-Fired	800	0.1	2.4
- Large, Coal-Fired	1000	2.7	5.2
- Large Oil (Imported) Fired	800	5.5	7.5
- Small, Heavy Oil-Fired Inland Location	1400	7.3	11.4
- Small, Wood-Fired	1500	3.0	10.00
Geothermal - Dry Steamfield	1400	n.a.	3.0
- Wet Steam/Hot Water Field	2800	n.a.	6.0
Nuclear - Large Multiple Units	1600	1.0	5.1
- Single Small Unit	2200	1.0	7.1
Solar Photovoltaic	20,000-30,000 ^{b/}	n.a.	100-300
Wind Generator	5,000-15,000 ^{b/}	n.a.	30-100

n.a. Not applicable.

^{a/} Investment cost includes cost of transmission and distribution

^{b/} Both solar energy and wind power are intermittent energy sources which require storage to make energy available on demand at all times. Investment costs given above are system costs with storage included.

Source : World Bank, Report No. 3076, Energy in the Developing Countries.

Coal is more abundant than other fossil fuels in African countries. Its technology of extraction and utilization is less complex than that of other fossil fuels. The price is also competitive in fuel and direct heat application.

B. Preconditions for increased coal utilization

The prerequisite to the expanding of coal production is an accelerated programme of exploration ~~general~~ geological information in Africa is lacking hence workable coal deposits are not defined. Geological information including characteristics of African coal must be well documented and disseminated. Exploration techniques such as seismetric and seismoacoustic methods are well known. The follow-up techniques of drilling and examination of core samples are conventional. Techno-economic information relating to exploitation includes the nature of the overburden, nature of strata between the coal seams, the thickness and dip of the seams, faulting and intercalation by bands of shale and mudstones.

Utilization of coal is guided by the physical, petrographic and chemical properties of coal. Results of proximate analysis (moisture, volatile matter, ash and fixed carbon) may be used for routine control or to establish rank of the coal or to ascertain the need for beneficiation. Results of ultimate analysis (carbon, hydrogen, nitrogen, oxygen and sulphur) are used for combustion calculations. Various applications require specification of the desired characteristics of the coal.

Having ascertained the techno-economic value of a coal deposit a decision to mine is taken. The recovery of coal is carried out either by surface or underground mining. Surface mining (open cast mining) is less costly than underground mining. There are two general methods of underground mining. In the **room-and-pillar** method, the coal is mined at relatively shallow working depth by cutting "rooms" in the coal seams and leaving "pillars" between the rooms to support the roof. Recovery of the coal is very poor by this method.

Longwall face (two parallel headings 100-200 apart) are driven into the seam at right angles to the main heading and the coal mined from the block between. Longwall mining employs continuous mining in modern mines. In the older mines the cycle of operation involves : undercutting the seam, drilling of blasting holes, blasting, face trimming, loading and conveying by conveyor or shuttle cars. Recovery is greatly improved by this method.

Infrastructure for transportation, handling and storage of coal is a very demanding pre-condition for increased utilization of coal in African countries. Transport of coal from the pit or mine to the ultimate consumer (power station,

coke oven, whole sale depot, etc.) is mainly carried out in specially loaded rail cars and for large quantities by specially equipped mobile loading, unloading and transfer of transportation and other facilities. The handling of transport modes is the following: order of importance: railway, truck, boat, and conveyor belt. Coal slurry (with or without coal in slurry) is a newly developed mode of transportation. Transportation over long distances is by rail carriers.

Coal handling and storage facilities are designed on the basis of speed and large volume of materials to be handled. Automation and systematic construction must be built with the design of facilities. Some of the modern concepts in coal handling and storage include: crane loading, storage - reclaiming system and multi-stage loading. A major barrier will be to develop this infrastructure simultaneously to the coal industry development. At the moment this infrastructure is inadequate.

C. Opportunities arising from interconvertibility of forms of energy

There are limits to the direct replacement of one form of energy by another. There is no substitute for coal for the internal combustion and jet engines according to the present state-of-the-art. Primary sources of gas and jet fuel, however, can be substituted. The dominant form of energy will continue to be heavy and light petroleum fuels.

Domestic fuel sources are gas, natural gas, electricity, charcoal, biomass and coal. Environmental considerations and cost are the major determinants of interconvertibility.

Synthesis gas from coal can directly replace natural gas as the raw material for ammonia and production of synthetic natural gas, alcohols and aromatic hydrocarbons. This is an important case of coal substitution in Africa. Electricity is the most convenient source of energy for lighting, industrial drives and domestic appliances. It is interchangeable with other forms for direct heating, cooling and space heating. Its generation can be achieved by several forms of primary energy systems, gas fired, fuel oil fired, coal fired, wind, solar, geothermal as well as tidal.

D. Utilization of coal for electricity generation

Thermal power plants are installed as a back-up to assure reliability of power supply in countries endowed with hydro resources. For those that are not well endowed, thermal power plants are primary sources of electricity. In coal producing countries, it is a common practice to install a coal fired

thermal power plant to utilize the low calorific value coal which would normally be discarded as overburden and would subsequently burn spontaneously. The electricity generated is sold at a credit to operations of the coal mine. As a matter of policy hydro-electricity generation is developed along side with thermal power plants so that at peak periods the thermal power plant can supplement the power system with extra supply. Most mining installations install on-site thermal power plants.

The Industrial Development Decade envisages an installed capacity of 216,000 MW by the year 2000 (an additional 20,000 MW over the existing). If we assume that about 25 per cent of this would come from coal fired plants, the potential coal market would be about 27 million tons annually for the 50,000 extra coal-based MW needed.

F. Opportunities for coal conversion

(i) Coal gasification

The first opportunity for coal utilization by gasification is the production of low calorific value gas mixtures produced by gasifying coal with air as the oxidizing agent yielding a product suitable for steam-raising, industrial process heating, or combined cycle of electric power generation. The second opportunity involves the coal gasification with oxygen and steam yielding synthesis gas suitable for the production of synthetic coal gas (SNG), methanol, ammonia, or using the gas for the Fischer-Tropsch synthesis.

(ii) Pyrolysis and coal liquefaction

Pyrolysis is intended to produce coal based liquid fuels that would replace petroleum based fuels. Gasification offers an opportunity for utilizing coal by producing liquid fuels by the hydrogenation of coal. Brown and bituminous coals have been experimented with yielding aviation gasoline, motor gasoline and gaseous hydrocarbons. Current effort is directed towards the production of coal-based crude oil (syncrude).

(iii) Economics of coal conversion^{1/}

Probable cost of syncrude depends on the experimental process used for techno-economic evaluation. Break-even costs have been estimated to be between \$12-\$13 per barrel. Total capital costs for a commercial plant handling:

^{1/} Role of coal in supplying the ECE Region with Energy and Raw materials in the Light of New Techniques of Coal Conversion and Utilization; UN Economic Commission for Europe ECE/COAL/72; 18 October 1982 pages 59-69.

between 25,000 and 30,000 tonnes of coal per day are estimated at \$1.5 to 2 Billion.

Under North American conditions capital costs of a 2,000 tonnes/day coal based ammonia plant using a Koppers-Totzek gasifier is \$360 million (compared with \$175 million for a natural gas based one of comparable capacity). A 2,000 t/d methanol plant based on Koppers-Totzek coal technology is estimated at \$323 million (compared to \$120 million for natural gas based comparable plant).

These few figures indicate a contradiction which is very common to process based industries. Well-tested and tried technology is cheaper than new technology. In the energy sector coal-based technology has been a response to escalating feedstock prices. Amortization of research and development costs contributes greatly to the high specific investments of coal based technology.

Numerous pilot plants have been constructed to demonstrate the techno-economic feasibility of Coal Conversion plants. Processes are diverse and conflicting claims are made with regard to their performance. It is therefore difficult to make an informed assessment of their usefulness to the African situation. It is therefore an important requirement that such evaluation be made prior to considering these conversion process as viable to our situation in Africa.

2. Increased utilization of coking coal

Iron and steel technology based on the blast furnace and basic oxygen converter (BOF) has been adopted as a basis for developing the iron and steel industries of, Algeria, Egypt, Kenya, Morocco, Nigeria, Tunisia and Zimbabwe. By 1985, the BOF route based steel capacity will be 3.1 million tonnes and 22.0 million tonnes by the year 2000. The potential market for coking coal will be roughly 9 million tonnes in 1985 and 25 million tonnes in the year 2000.

Specifications for Metallurgical Coal are very stringent. Coals for coker-making require proper preparation before carbonization. Preparation is conducted for the purpose of reducing the ash (5-6 per cent) and sulphur (0.6 - 1.4 per cent) content. Blending ensures that coal is uniform hence the product of carbonization will also be uniform. The following reasons are advanced in support of coal preparation for metallurgical coke:

- (i) high ash content means less fixed carbon in the coke and more slag volume in the blast furnace hence more coke per ton of iron and less iron production;

- (ii) for each per centage point of ash reduction in blast furnace coke, some 3 - 6 per cent increase in iron production can be achieved;
- (iii) high sulphur content in the coke means more limestone in the blast furnace. The iron balance will be reduced in the burden hence low blast furnace productivity;
- (iv) good quality coal leads to a good coke.

Blending of coal for coking purpose is associated with uniformity of quality of the admixture and also helps to :

- (i) improve the chemical and physical quality and uniformity of the coke;
- (ii) control the pressure developed in the oven by carbonization process;
- (iii) control the yield of products;
- (iv) expand the utilization of coals with poor coking characteristics.

In view of the fact that coking coal endowed African countries will not necessarily install iron blast furnaces it is envisaged that these countries (Madagascar, Mozambique, Swaziland, Tanzania, Zaire and Zimbabwe) may wish to produce coal or coke and sell their products to African countries with iron furnaces (namely : Algeria, Egypt, Morocco and Nigeria.)

STRATEGIES AND MODALITIES FOR CO-OPERATION IN COAL PRODUCTION AND UTILIZATION

1. Preconditions for co-operation

(a) Exchange of Information

An information system facilitating free flow of publications, reports of geological investigations and results of research and development is an essential means of promoting co-operation in the field of coal development. Regular seminars, study tours and Conferences relating to coal production and utilization will lead to greater awareness of the potential role of coal in African economies. Joint research and development work between African countries as well as other countries with the necessary experience in the field of coal will enhance the accumulation of expertise, experience and know-how. Algeria, Egypt and Nigeria will play a leading role in this respect.

(b) Expanding coal production

An accelerated programme of exploration is a prerequisite for expanding coal production. Exploration for coal has been the least of priorities in the mineral industries of Africa. In the past, mineral industry projects were initiated and promoted by multinational corporations who were not interested in coal. Undoubtedly major coal fields await discovery in many African countries. Research and development effort aimed at classifying and characterising the African coals will need to be undertaken. Those countries with research and development facilities will need to put themselves at the disposal of those without. Egypt and Algeria will need to play a key role. Techno-economic information regarding mining and beneficiation will need to be collected and compiled for easy reference and use by member states. Due regard will need to be given to : improved techniques of exploration of reserves, optimized extraction technology minimization of losses, adaptation of existing technologies and development of new ones to recover untapped coal reserves.

(c) Evaluation of new technologies for coal conversion

A study group comprising experts from coal producing and consuming countries and ECA/UNIDO will need to be constituted to evaluate the numerous coal conversion technologies that have been reported in articles and paper over the last few years. The objective will be to select those that are of great promise to the African situation. These would be subjected to a much more detailed appraisal with a view to promoting cost effective coal conversion technologies for African countries in response to the escalating prices of

petroleum products. These coal conversion technologies that will offer an opportunity for African countries to enter into the petrochemicals market will also be given attention. The study group will pay particular attention to areas where petroleum feedstocks can be replaced by coal.

B. Conclusions

By the year 2000 Africa could produce and consume 30 million tonnes of thermal coal and 25 million tonnes of coking coal. This would entail the development of new coal mines with expensive social and economic infrastructure. Planning for this investment needs to be done now. Planning should include establishment of transport and power supply networks towns and settlements with social facilities. Productive investments should also be planned now covering: thermal power stations; coke oven installations and metallurgical plants.

Development of the coal industry will require scientific, technical, research, design and development institutions to serve the needs of the coal industry. Increased coal utilization will depend on careful selection of cost effective coal conversion technologies.

C. Recommendations

(a) At national levels

Efforts at national levels will concentrate on drawing up measures aimed at improved utilization of coal reserves such as:

- (i) introduction of longwall systems for coal seams where room-and-pillar methods are being used;
- (ii) improvement in organization and management of coal industries including estimation of reserves, planning and development of deposits;
- (iii) review and formulation of mining regulations aimed at improved utilization of coal;
- (iv) undertake energy planning studies with a view to identifying areas of coal substitution and drawing up long-term supply demand balances for each source of energy;

- (v) reappraise coal field resources, evaluate coal field infrastructure for transport, storage and handling and include, if possible, tariffs and other service charges, if possible, ports, waterways and coal terminals;
 - (vi) planning for long-term development of coal field resources with foreign specialists;
 - (vii) conduct re-investment and foreign investment studies in all essential areas of coal development.
- (1) 1 sub-regional and regional levels
- (i) consultations involving an international agency in all related coal development and utilization of coal;
 - (ii) intensive research and development of coal processing, production and utilization of coal;
 - (iii) joint venture in the development of coal mines, beneficiation plants and associated infrastructure.